Release condition of a metallic dust particle from plasma-facing wall

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Dust particles with different sizes, shapes and compositions are observed in plasma during discharges and they accumulate after discharges on plasma-facing wall (PFW). The elements of dust particles originate in structure materials of divertor plates and first wall. It is supposed that the dust particles are generated by plasma-wall interaction and transported toward the core plasma as impurities. Therefore, release from the PFW and dynamics of dust particles need to be studied and controlled, but they are not well understood so far.

In this study, the release condition of the dust particle from the PFW is investigated. Forces on a spherical and metallic dust, which radius is much smaller than the Debye length, are analyzed theoretically and the plasma condition for the dust particle release is derived.

1D sheath plasma model is applied. Wall potential is determined by floating condition. At the sheath entrance, the velocity distribution functions of electrons and ions are assumed to be Maxwellian and shifted-Maxwellian, respectively. Ion drag force due to absorption of ions, electrostatic force due to sheath electric field and gravitational force are considered as forces on the dust particle (Fig.1). Friction force due to Coulomb scattering of ions is found to be negligible in this configuration.

The release condition is determined by the quantity $R_d/n_{se}T_e$, where R_d, n_{se} and T_e are the dust radius, electron density at the sheath entrance and electron temperature, respectively. Plasma ions push the dust particle toward the wall, which means the smaller dust particle in higher electron pressure has a possibility to be released from the PFW. For example, a tungsten and carbon dust particle with $R_d = 1\mu$m in $n_{se} = 10^{18}$ m^{-3} and ion temperature $T_i = 0$ is released at the electron temperature higher than 7.1 and 0.71 eV, respectively (Fig.2: $\overline{F} \equiv F/\pi R_d^2 n_{se} T_e$).

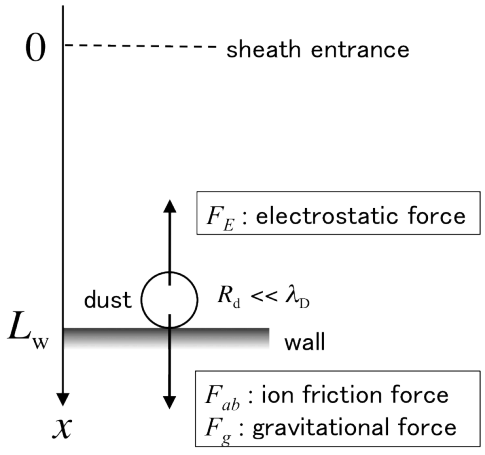

Fig. 1 Model configuration and forces on dust particle. The dust particle is released in the case of $F_E > F_{ab} + F_g$.

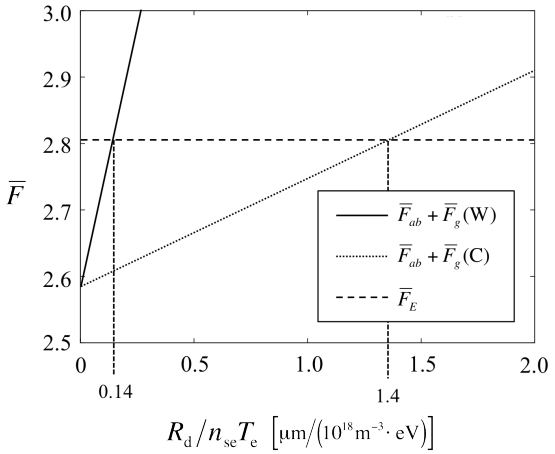

Fig. 2 Forces on a tungsten and carbon dust on the wall at $T_i = 0$. A tungsten and carbon dust particle is released when $R_d/n_{se}T_e$ is less than 0.14, 1.4, respectively.